REMARKS

Upon entry of the amendments, claims 1-10 and 21-24 will be pending in the application. Non-elected claims 11-20 have been canceled and will be pursued in a divisional application at a later time. Applicants have added new claims 21-24 to the application. No new matter has been introduced by these amendments and no claim fees are believed to be due.

Claim Rejections – 35 U.S.C. § 103

The following obviousness rejection were issued in the Office Action of September 15, 2003:

1. claims 1-7 and 9 are rejected in view of Horino (US 6,072,197) and Tanaka (US 5,909,036); and
2. claims 8 and 10 are rejected in view of Horino, Tanaka, and Tomiya (US 6,576,533).

Regarding the first rejection, The Office Action provides reasoning pertaining to the rejections of independent claim 1 (plus dependent claim 2-5) and independent claim 6 (plus dependent claims 7 and 9). Claims 1-5 of the present application relate to non-C-plane growth and claims 6-10 relate to facet growth.

The Examiner admits that the primary reference, Hirono, fails to disclose the use of oxygen to dope GaN set forth in independent claim 1. To alleviate this failing, the Examiner relies on the teachings of Tanaka.

Applicant has carefully considered the rejection of claim 1, but respectfully requests that the rejection be withdrawn. Claim 1 sets forth "growing a gallium nitride bulk crystal upon the non-C-plane gallium nitride seed in vapor phase". The claim sets forth <u>growing a GaN bulk crystal</u>. It is Applicants' belief that Horino fails to hint, suggest,

or teach the production of a GaN bulk crystal in the <1–100> direction. Applicants believe that there is a significant difference in producing 500-3000 μm thick GaN substrates and producing films of 0.1-2μ thickness.

Furthermore, Applicant believes that claim 1 is further distinguished from the prior art because it clarifies orientation dependence of the crystal for absorbing oxygen, i.e., "non-C-plane". The cited prior art fails to mention non-C-plane growth. Hence, the cited prior art most likely used C-plane growth, which is conventional. The most prevalent growth of GaN thin films is C-plane growth, which maintains a flat C-plane surface of GaN films on C-planes of sapphire (Al_2O_3) single crystal substrates. When a foreign material is used as an undersubstrate for growing GaN films, the undersubstrate should have three-fold or quasi-three fold rotation symmetry. Thus, when GaN films are grown on a foreign material substrate, e.g., sapphire (Al_2O_3) undersubstrate or silicon carbide (SiC) undersubstrate, a GaN film would be grown in the c-direction which is perpendicular to C-plane.

The present inventor, Mr. Motoki, discovered that C-plane growth inhibits oxygen doping of GaN. Mr. Motoki discovered that other orientations besides the C-plane have a favorable function of absorbing oxygen, which is an <u>unexpected result</u>. For example, {11-20} and {1-100} (in particular {11-22} and {1-101}) planes have unexpected results in regards of oxygen doping. For example, A-planes {11-20} planes and M-planes {1-100} have an oxygen introducing performance of more than fifty times that of the C-plane. Reference is made to page 20 of the application. Conventional C-plane growing GaN films are doped with silicon (Si), because of the poor results with oxygen. This anisotropic orientation dependence was far beyond the common sense of the skilled persons in the art at the time the present application was filed.

Applicant provides the following additional comments to rejection of claims 1-5. Horino's invention is not a substrate invention but a device invention. First Example of Horino uses an n-type GaN (1-100) substrate 11 (column 11, line 36). Second Example uses an n-type GaN (1-100) substrate 21 (column 13, line 32). Third Example uses an n-type GaN (0001) substrate 31 (column 15, line 20). Fourth Example adopts an insulating $LiA1O_2$ substrate 35 (column 16, line 1). Fifth example of Horino uses as SiC (11-20) substrate 41(column 22, line 59). Sixth Example adopts a sapphire (11-20) substrate or a 6HJ-SiC (11-20) substrate 71 (column 27, line 41). Thus, First and Second Examples of Horino use a (1-100) GaN substrate.

However, Horino's invention is a surface-emitting laser diode with fixed polarization. A laser light beam is emitted from the top in a vertical direction. Laser rays reciprocal between an upper dielectric multilayered mirror and a lower dielectric multilayered mirror. If the crystal layers have C-planes, the direction of the reciprocal rays is parallel to the c-direction. Polarization vectors lies in xy-plane. Xy-direction is the a-,b- and d- axes in the c-plane crystals. No anisotropy exists in xy-plane. A polarization vector can take two directions of x-direction and y-direction. Uncertainty of the polarization disturbs laser amplification function, which impedes laser oscillation. Horino tried to introduce anisotropy for the polarization of laser beams by replacing an a-plane surface crystal substrate. In a device grown on an a-plane, laser beams would have polarization in yz-plane which has anisotropy. The anisotropy uniquely determined the direction of polarization. The determined polarization is favorable for a vertical oscillation laser. Then, Horino adopted an a-plane substrate for assisting laser oscillation by preventing polarization from fluctuating in the xy-plane.

Since Horino's invention is a device invention, Horino describes nothing of preparing the substrate. Horino fails to teach the preparation of the (1-100) GaN substrate. Applicant believes that Horino could have hypothetically made a c-axis growing GaN (0001) crystal on an SiC(0001) undersubstrate, a GaAs(111) undersubstrate, or other three-rotation symmetric undersubstrates, because no large GaN substrates exist in nature. Obtaining a tall c-axis grown GaN (0001) crystal, Horino would slice the GaN crystal in a (1-100) plane vertical to the surface (0001) and would obtain several (1-100) GaN starting substrates. Since (1-100) is a cleavage plane, slicing would be easy for Horino. Then, Horino would not take any step of growing a GaN substrate crystal in a <1-100> direction. Instead of the <1-100> direction, Horino would grow his GaN crystal in the ordinary <0001> direction. Horino implies nothing of the non-C direction growth of bulk crystals.

As discussed above, Horino gives no hint of making a GaN bulk crystal in the <1–100> direction. Horino most likely would take an ordinary step of making a c-axis growth on a C-plane foreign undersubstrate. Thus, Horino lacks the step of "...growing a gallium nitride bulk crystal upon the non-C plane gallium nitride seed."

The Office Action sets forth that "Fig. 5A shows a faceted structure formed from a {0001} GaN (i.e. c-plane) (col. 15 third example). The facet is of the {11-21} variety. The facet plane is described as not limited in line 48."

Applicant asserts that Horino's Fig. 5A is an improvement of a TS (Terraced Substrate) structure which has been well known in infrared GaAs lasers. A rectangle (0001) substrate should have been prepared and would have been etched in the slanting slope. The facet 32 was not a beginning surface for making a substrate but a final surface made by etching. Horino reduced a finished substrate down to the slope by etching. The present invention increases the substrate by piling further GaN on the facets by supplying

GaC1, NH_3 and oxygen. No dopant can be introduced to Horino's substrate via the slop in the etching process, since etching does not add matter to the substrate but deprives the substrate of matter. Suggestion of the etched slope 32 of Horino's Fig.5A (Terraced Substrate type laser) give no hint of doping via facets into substrates.

Applicant also wishes to clarify that Horino fails to give any teaching of making a GA bulk substrate. Horino told us film formation A1GaN, A1InGaN, GaN thin films on the (1-100) GaN crystal. Horino doped his n-type $A1_{0\ 1}Ga_{0\ 9}N$ film on the GaN substrate of his First Example with silicon. Column 11, lines 44-45 says, "Ai_2H_6 at 0.00001 to 0.002 μmol/min., for example, 0.00007μmol/min."

Horino doped his n-type $A1_{0\ 4}Ga_{0\ 3}IN_{0\ 3}N$ film on the (1-100) GaN substrate of his Second Example with silicon. Column 14, lines 41-42 say, Si_2H_6 at 0.0001 to 0.002 μmol/min, for example, 0.00007 μmol/min."

Horino used silicon (Si) as an n-dopant for making N-A1GaN and n-GaN thin films in his First Example and his Second Example. Use of silicon as n-dopants for InGaN, A1InGaN or GaN films is commonly described for all his other examples (n-type films grown on Sic-, sapphire-, $LiA1o_2$ – undersubstrates) in Horino. No n-dopant exception silicon appears in Horino. Horino knows anything but silicon for a n-dopant.

Table 1. Comparison table – Horino and Motoki

	Horino	Motoki
Growing matters	Thin films (A1GaInN, InGaN, GaN) 0.1μm - 2μm	GaN 500μm-3000μm
Substrate	GaN, $LiA10_2$	GaN
Substrate n-dopant	None --- $LiA10_2$ Silicon (Si) --- GaN	Oxygen (O) --- GaN
Substrate growth surface	C-plane (0001)-plane	Non-C-plane {kk-2kh}, {k-k0h}
Film growth surface	(1-100) plane	
Film n-dopant	Silicon (Si)	

Non-C reason	Polarization fixation	Oxygen doping facilitation

Tanaka (USP5,909,036), which is assigned to the assignee of the present application, has been cited for complementing Horino. The Office Action sets forth that "Doping of these materials is described as accomplished by adding impurities in col.8 lines 15-28. N-type nitrides are formed by adding oxygen to the nitride. Addition of the doping gas during growth is suggested in col.9 lines 35-45."

Column 8, lines 16-27 details:

> "In the case of a single crystal film of a III-V nitride in a semiconductor device, the electric conductivity is controlled by adding impurities. Specifically, in the single crystal film of a III-V nitride according to the present invention, as such impurities, at lease one element selected from among silicon, tin, oxygen, sulfur, selenium, tellurium and the like may be added to impart n-type conductivity, while at lease one element selected from among zinc, beryllium, magnesium, potassium an the like may be added to impart p-type conductivity, For the low-temperature growth buffer layer, as with the single crystal film of a III-V nitride, the electric conductivity may be controlled by adding impurities."

Tanaka implies nothing about oxygen except that it could be used to impart n-type conductivity. Tanaka mentions nothing of an activation rate of oxygen, nothing about how to dope films with oxygen, and nothing about how oxygen makes donor levels in films.

Tanaka adopted aluminum nitride substrates (AlN) instead of GaN as a substrate. Tanaka teaches aluminum nitride based LED devices. Applicant believes that since Motoki's invention is a substrate invention, Tanaka's AlN substrate manufacturing should be compared with the outstanding Motoki's oxygen-doped GaN substrate. However, Tanaka's AlN substrate is undoped and the AlN is an insulator. No dopant is contained in Tanaka's substrate of AlN. Tanaka has no counterpart to the present Motoki's invention of fabrication of the oxygen doped GaN substrate. Since n- or p-doping is impossible for

AlN, AlN cannot be converted into n-type by doping like sapphire. Tanaka has no teaching of making an n-type GaN substrate bulk.

Table 2. Comparison table – Tanaka and Motoki

	Tanaka	Motoki
Substrate	AlN C-plane	GaN non-C-plane
Substrate property	Insulating	n-type
Substrate N-dopant	None(impossible)	Oxygen (O)
Growing matters	Thin films (AlInN, InGaN, GaN) 0.1μm-2μ	GaN substrate 500μ-3000μ
Substrate growth surface	C-plane (0001)-plane	
Film n-dopant	Si = suitable Potential candidates Sn, O, S, Se, Te (no embodiments)	

Tanaka's invention is not a substrate invention but a device invention. The AlN device has a structure of p-GaN/n-InGaN/n-GaN/AlN. The undoped substrate of Tanaka suggests nothing of the current Motoki invention of doping a GaN bulk crystal substrate with oxygen.

Applicant further notes that Horino reveals silicon doping to (1-100) A1Gan, InGaN, GaN films and Tanaka reveals silicon doping to (1-100) A1GaN, InGaN, GaN films. Horino doped his GaN substrate with Si. Horino doped the $LiA1O_2$ substrate with nothing. Tanaka doped his A1N substrate with nothing. Neither Horino nor Tanaka grew their substrates, GaN, $LiA1O_2$ and A1N in c-direction by maintaining C-plane surfaces instead of non-C-direction. Table 3 denotes a comparison between a combined Horino/Tanaka and Motoki.

Table 3. Comparison table – Horino/Tanaka combination and Motoki

	Horino/Tanaka	Motoki
Growing matters	Think films (AlInN, InGaN, GaN) 0.1μm - 2μm	GaN Substrate 500μm-3000μm
Substrate	GaN, $LiAlO_2$, AlN	GaN
Substrate n-dopant	Si ---GaN None --- $LiAlO_2$, AlN	Oxygen (O) --- GaN
Substrate growth surface	C-plane (0001) plane	Non-C-plane {kk-2kh}, {k-k0h}
Film growth surface	(1-100) plane --- Hirono (0001) plane --- Tanaka	
Film n-dopant	Silicon (Si) Potential candidates Sn, O, S, Se, Te	
Non-C reason	Polarization fixation	Oxygen doping facilitation

Applicant asserts that a combination of Horino/Tanaka is quite different from the present application by Motoki. The combined Horino/Tanaka makes substrates not by non-C-plane growth but by C-plane growth. The combined Horino/Tanaka uses silicon as an n-dopant for substrates. The combined Horino/Tanaka does not show that oxygen is a good n-dopant for substrates. The combined Horino/Tanaka describes nothing about an activation rate of oxygen in GaN. The combined Horino/Tanaka does not indicate mysterious anisotropy which prevents C-surface from absorbing oxygen.

Therefore, Applicant urges that claim 1 is allowable as are dependent claim 2-5. Likewise, Applicant asserts that independent claim 6 is not obvious in view of the cited prior art. As discussed above, the cited prior art fails to detail "growing a gallium nitride crystal with facets". Therefore dependent claims 7-10 would also be allowable in view of the cited prior art.

Regarding the second rejection, Applicant provides the following comments regarding the rejection of claims 8 and 10. Tomiya (USP6,576,533) invented an improvement of an epitaxial lateral over growth (ELO) of GaN, AlGaN, InAlN films on sapphire substrates. The ELO aims at reducing dislocations by horizontal direction growth

as shown in Fig. 10B of Tomiya. Tomiya shows film facets in Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9C, 10A, 10B, but all the facets are buried as shown in Fig. 1, 2, 3, 4, 5, 6, 7, 8, 10B, 12B and 13. Fig 13 shows a complex substrate 40. A lower half (6) of the substrate (40) is an insulating sapphire (6). A buffer layer (7) is a thin GaN (0001) film which grows in the C-plane. Facets 1 are made between an underlying GaN layer 2 and a grown/buried GaN layer 3. But, the V-grooves will be soon buried by the upper grown/buried layer 3. The facets does not survive and are not maintained.

Column 8, lines 19-22 of the cited reference explains in "this way, as shown in FIG.10B, GaN is grown to perfectly bury the grooves 10, to form the selectively grown/buried semiconductor layer 3 having a flat surface."

The underlying layer and the overcoating layer are non-doped GaN. The combined GaN layers 2/3 is an insulator without n-dopant. The V-groove's purpose is to reduce dislocations but not to dope with impurities. Indeed, Tomiya doped the upper/lower zigzag layers 2/3 with nothing. Since the bottom is an insulating sapphire, the upper layer needs not conducting. Then, the upper zigzag structured GaN layers are insulators. The zigzag GaN layers are undoped. The combined layers 2/3 is an insulator of non-doping.

Other upper films 22, 23 are n-doped in Tomiya. The n-dopant is silicon. Uniquely, Si is adopted as an n-dopant in Tomiya.

Column 11, line 65-column 12, line 5 of Tomiya teaches:

> "Then, a first contacting layer 21 made from n-type GaN doped with Si and having a thickness of 2μm, a first cladding layer 22 made from n-type A1GaN alloy crystal doped with Si and having a thickness of 0.5μm, and a first guiding layer 23 made from n-type GaN doped with Si having a thickness of 0.1μm are epitaxially grown in sequence on the flat surface of the selectively grown/buried semiconductor layer 3."

Tomiya fails to teach impurity doping through facets. Tomiya's facets are buried and would not absorb a dopant. Furthermore, Tomiya's facet containing portion is an upper half of an insulating substrate.

Table 4. Comparison table – Horino/Tanaka/Tomiya combination and Motoki

	Horino/Tanaka/Tomiya	Motoki
Growing matters	Thin films (AlInN, InGaN, GaN) 0.1μm-2μm	GaN substrate 500μm-3000μm
Substrate	GaN, $LiAlO_2$, AlN, GaN/GaN/sapphire	GaN
Substrate n-dopant	Si --- GaN None --- $LiAlO_2$, AlN None --- GaN/GaN/sapphire	Oxygen (o) --- GaN
Substrate growth surface	C-plane --- GaN, $LiAlo_2$, AlN (0001) plane Facet/buried GaN/GaN/sapp.	Non-C-plane {kk-2kh}, {k-k0h} Unburied facets
Film growth surface	(1-100) plane --- Hirono (0001) plane --- Tanaka, Tomiya	
Film n-dopant	Silicon (Si) Potential candidates Sn, O, S, Se, Te	
Non-C reason	Polarization fixation Dislocation reduction	Oxygen doping facilitation

The examiner refused claims 8, 10 by a combination Horino/Tanaka/Tomiya. Motoki's invention is a method of making GaN substrates. Horino/Tanaka is not a substrate invention but a device invention. Only Tomiya relates to making an ELO made uppercoating substrates. Tomiya's GaN is not freestanding but a dependent layer fixed upon a sapphire substrate (GaN/GaN/sapphire).

Tomiya did not remove the sapphire substrate. Thus, the upper GaN is not freestanding. The (GaN/GaN/sapphire) upper GaN complex layers 2/3 are not conductive but insulating. The upper GaN complex layers are undoped. Thus, an imaginary combination Horino/Tanaka/Tomiya describes nothing of oxygen doping via facets in substrates of GaN. Thus, the combination Horino/Tanaka/Tomiya would not make the present invention obvious.

The cited prior art fails to suggest substrate oxygen doping via facets.

New Claims

New claim 21 is similar to claim 9, but sets forth only the {11-22} facets. This claim is allowable for reasons set forth above. Likewise, new claim 22 only sets forth the {11-21} facets.

New claims 23 and 24 are supported by the subject matter set forth on page 19. These claims are allowable based on their dependency from claim 1.

CONCLUSION

Applicants respectfully request allowance of the application. If any additional fees are due in connection with the filing of this response, such as fees under 37 C.F.R. §§ 1.16 or 1.17, please charge the fees to Deposit Account No. 02-4300. Any overpayment can be credited to Deposit Account No. 02-4300.

Respectfully submitted,

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